



Deep renovation in existing residential buildings through façade additions: A case study in a typical residential building of the 70s

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ABSTRACT

The aim of this paper is to evaluate and illustrate the energy saving potential of the façade addition on existing and low energy performing block buildings in different climatic contexts.

To achieve this purpose, the paper illustrates some outstanding case studies on deep renovation through façade and volumetric additions, as reference possible solutions towards energy renovation. To further assess the energy potential of these transformations, the same solutions have been applied to a reference building in Bologna. In particular, a selected apartment of typical building block has been investigated and simulated in detail, to identify the buildings' energy requirement and propose different retrofitting hypotheses towards nearly Zero Energy Buildings (nZEBs). Simulations of these different hypotheses resulted in corresponding diverse energy performances, from the very low grade of performance in "as built" scenario, up to nearly zero energy demand, for selected technological solutions applied in specific climatic contexts. To further estimate the energy impact the same apartment has been "extracted" from its original climatic context and energy simulations have been also carried out in two different climatic zones. Obtained results prove that façade additions are a very powerful solution towards the aim of zero energy in existing buildings.

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1. Introduction

More than 70% of the European existing buildings have been built between the '50s and the '70s, in the total absence of any specific regulation regarding buildings performances, energy consumptions and savings. As a matter of fact, the existing building stock in EU consists in the larger majority of buildings built after the Second World War. These buildings, constructed during the economic boom of the 60s and 70s, show poor thermal performance and high fuel consumption [1]; in fact, their construction has been based on a process that focused on minimizing time and overall costs and this process produced poor quality buildings, in terms of energy, construction and social performance. As a result, this category of buildings is one of the first extents on which action should be taken to reduce energy consumption and emissions of pollutants [2]. The majority of these buildings are stand-alone blocks. As reported in [3] in 2015, more than 4 out of every

10 persons (42.0%) in the EU-28 lived in flats, close to one quarter (24.1%) in semi-detached houses and one third (33.3%) in detached houses. The proportion of people living in flats was highest, among the EU Member States, in Spain (65.9%), Latvia (65.0%) and Estonia (62.6%), while the highest proportions of people living in semi-detached houses were reported in the Netherlands, the United Kingdom (both 59.9%) and Ireland (51.6%); these were the only Member States where more than half of the population lived in a semi-detached house.

Thus, energy renovation represents the most urgent, yet possible and realistic perspective for the existing building stock. In the retrofitting process the rate of the energy performance in the "as built" initial state and after renovation [4,5] is one of the key performance indicators but there are other equally important factors: the increase of construction quality, the corresponding life cycle extension, the additional economic value, the adaptation of the living space according to the users' needs. In other terms, the social and architectural upgrade has to be considered as non-energy related aspect with the highest potential to decrease energy con-

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sumption in existing buildings while improving the quality of life for residents.

In the last decade an awaking policy focused on the protection of the environment in Europe with a special care to energy waste in the building sector [6]. All Member states starting from the signing of the 1997 Kyoto Protocol, have set themselves new goals whose purpose is the reduction of greenhouse gas emissions and energy consumption. In 2007, these directives have undergone a renewal of the objectives to be achieved by 2020: 20% increase in the share of renewable energy sources, decrease by 20% the energy consumption and 20% improvement in energy efficiency, or what is called “Horizon 2020” [7]. In the last decade, the European Parliament, amending the 2002 Energy Performance of Buildings Directive, has approved a recast of the Directive proposing that all new buildings built after 31 December 2018 will have to be buildings with very high energy performance and their very low amount of energy required should be covered to a very significant extend by energy from renewable sources produced on-site or nearby [8].

According to Monge-Barrio and Sánchez-Ostiz [9] sunspaces are considered the elements of passive architecture responding to various climatic conditions and are designed as solar heating systems and must avoid causing overheating and discomfort in the space to which they are added. The European Directive 2010/31/UE, “on the energy performance of buildings” (EPBD2010) [10] clarifies that the efficiency of buildings must be achieved throughout the whole year period, and not only with regard to facilities, but also to “passive heating and cooling elements, shading, indoor air-quality, adequate natural light and design of the building”.

The addition of a sunspace can realise significant gains in energy efficiency. This can amount to around 30% when compared with a direct gain equivalent, though this varies according to climate and latitude where buildings benefit from southern locations. [11]

1.1. Sunspaces and buffer zones as a powerful tool for deep energy renovation: boundary conditions for an in-depth investigation of add-ons

Glazed spaces have been in the center of the architectural interest for many years [12–14]. The design of glazed areas when connected to sunspaces can be designed taking into account parameters like heat losses, storage of solar radiation, solar protection and minimization of cooling and heating needs [15]. Mihalakakou [16] investigated the energy saving potential of a sunspace on different climatic conditions in various climatic zones around Europe by showing that it is an effective solution during the winter.

According to Bataineh and Fayez [17] the use of sunspace when is oriented in the south leads to the maximum reduction of heating load. The sunspace, usually placed on the south side of a building is regarded as one of the most effective solar systems because of its potential as an energy collecting system and also because of its morphology. Mihalakakou and Ferrante [18] have demonstrated that sunspaces can be an appropriate and effective system during the cold period of the year.

However, they very often demonstrate overheating during the warm period of the year, especially in Mediterranean countries. In fact, to be effective during summer period, the overheating problem of a sunspace needs to be reduced by decreasing the cooling loads.

Sunspaces have their design focused on maximum solar collection, which results inappropriate in summer conditions, where avoiding overheating caused by solar radiation is a must. In temperate climates, with warmer summers are needed solutions, which result in a lower energy demand and adequate comfort. In this type of climate, south orientation of facades is optimal for solar gain in winter, and is an appropriate for solar protection sys-

tems in summer [9]. In climates where sunspaces work as a solar heating system in winter, the approach is that they should not contribute to overheating in the housing in summer, and if they do, measures to prevent this are proposed. In summary, optimized solutions are looked for throughout the year. Mihalakakou [19] and Oliveti et al. [20] studies compared the use of sunspaces in different climatic conditions. The first verified that these elements contribute significantly to the reduction of heating loads in winter in the European cities of Milan, Dublin, Athens and Florence, but create serious overheating in Mediterranean areas such as Athens, through energy simulation. To avoid overheating, a combination of three passive techniques is proposed. Oliveti studied and compared through simulation, behavior between three cities of Italy, and checked that sunspaces do not cause overheating in these latitudes, if they are shaded and ventilated properly, reaching the sunspace a temperature close to the exterior one, so that in the cities of the study, the sunspaces can be used practically throughout the year. Other studies analyzed the behavior of sunspaces in buildings and specific locations. For example Bataineh studied the efficiency of sunspaces in Amman (Jordan) throughout the year with simulation [21], finding that in summer they suffer serious overheating, unless using passive techniques of night ventilation and solar protection (in this case, interior curtains), concluding that with a sunspace, global heating and cooling loads are reduced in 42%.

This research concluded that the use of the sunspace is closely linked to a design that allows adequate ventilation and solar protection in summer.

The following section focuses on the evaluation of the energy performance of existing buildings as the necessary and preliminary step to define the most appropriate solutions to achieve the reduction of buildings' energy requirements and examine whether and how they can be partially or totally turned into nearly ZEBs.

The study has been developed on the real case of a social housing compound of the '60s, with a typical structure of reinforced concrete and prefabricated walls. The building block is inserted in a large urban setting consisting of similar buildings and a suburb located in the northern peripheral area of Bologna.

1.2. Outstanding examples in architecture building practise

The transformation of Tour Bois Le Pretre (Fig. 1) by the French architect Frédéric Druot [22,23] is a significant example of deep renovation combining energy retrofit with architecture quality and social sustainability.

It consists of a radical transformation of a tower building in a suburb of Paris, constructed on 1962 by the architect Raymond Lopez. The building is developed on 16 levels (50 m height), which accommodates 4 to 8 residential units in each floor, almost 100 in total. The 1999 new law in France enforced external insulation to the whole building and as a result, the interior spaces were decreased. The result of the addition of pre-fabricated extensions, winter gardens and balconies on a lightweight façade was the extension of two meters of living space and one meter of balconies. The construction of the new façade and the volumetric addition resulted in an increase of space for balconies and sunspaces for existing units, an additional increase of space in existing units, with a consequent growth of the tenants' number. In parallel, the energy performance of the building has been powerfully upgraded. By the addition of the sunspaces and the winter gardens, the original surface of 8900 m² resulted to 12,460 m² and the new organization of the apartments, the technical improvements and mainly the addition of the winter gardens led to the reduction of the energy consumption to almost 50%.

A similar, outstanding example is given by the renovation projects by C.F. Møller Architects, whose work is focussed in ar-

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